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METHOD AND SYSTEM FOR AUTOMATICALLY PARKING VEHICLES

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METHOD AND SYSTEM OF AUTOMATICALLY PARKING VEHICLES

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Field of the Invention

[0001] The present invention relates generally to a parking structure and in particular, to a method and system of automatically parking vehicles.

Background of the Invention

[0002] Existing automated parking garages and associated technologies pursue the goal of reducing the average amount of space required to park a car. The most rudimentary form of automated parking involves replacing ramps with an elevator or lift system. More sophisticated systems employ materials handling technologies to maneuver vehicles on systems of vertical lifts and horizontal tracks. Over the years, a variety of such systems have been described. The major distinctions are that the existing systems employ pallets or direct carrier mechanisms or such systems are exclusively vertical, or combine horizontal and vertical movement mechanisms.

[0003] Several systems employ pallets to support vehicles during the handling process. In these pallet-based systems, the customer arrives at the parking garage and drives his or her car onto a pallet assigned to it for the duration of its storage. A carrier then arrives from a location within the garage and lifts the pallet. The carrier then moves the pallet to a parking space on the same floor or to a lift that carries the pallet to a different floor. If the pallet is moved to a different floor, a different carrier meets the pallet at the lift and moves the pallet to its assigned storage location. The floor plan of such garages is organized by a perpendicular arrangement of longitudinal circulation tracks and transverse tracks that provide access for the carrier to store and retrieve the pallets. Typically, a carrier transports a pallet to the intersection adjacent to the designated storage location, and a mechanism transfers the pallet off of the carrier into the storage position on the transverse track. The depth of storage of the pallets along the transverse axis is generally limited to the space adjacent to the

circulation track, plus one or two additional tandem spaces. The space is limited due to the difficulty of shuffling pallets to positions adjacent to the circulation track which are accessible to the carriers. This system is also disadvantageous, because the entire parking structure must be built and configured to allow the carriers to move thereabout to carry the pallets to and from their storage locations. In addition, since the system depends on the carrier(s) to store and retrieve the vehicles, the system may take a substantial amount of time to retrieve or store a vehicle during peak parking/retrieval times.

[0004] In other parking system, such as direct handling systems, the customer drives his or her vehicle onto a cradle that supports the vehicle's tires. A comb-like handling device then lifts the vehicle off the cradle and carries it to its storage location, where the vehicle is placed on another storage cradle. Where direct handing is used in horizontal configurations, the carrier mechanism runs along a longitudinal track and deposits vehicles on cradles positioned adjacent to the track. Several direct-handling systems are known that use an elevator-like mechanism and a turntable to access storage spaces adjacent to an elevator shaft. In some prior art garages, an elevator or crane mechanism travels along the longitudinal axis of a multistory space, storing and retrieving vehicles or pallets onto racks adjacent to the vertical hoist way. These garages have the same disadvantages as the system described above.

[0005] Thus, a universal disadvantage of the prior art systems is that the garages are organized into dedicated areas for carrier circulation and vehicle storage. These circulation tracks are predetermined in the design of the installation, and the allowable storage depth off the circulation track determines the capacity and space efficiency of the garage. The relationship between the longitudinal axis and the transverse storage racks also creates a fixed modular dimension that dictates how well a given prior art system will fit on any given piece of land or within any given building. In addition, since circulation tracks occupy dedicated areas, these existing systems are limited in storage efficiency by the ratio of circulation areas to storage areas. In addition, as stated above, during the storage/retrieval process, the carrier mechanism for moving the vehicle must travel to the vehicle storage space to pick up the loaded pallet and stored vehicle. The need for the carrier to travel from its waiting position to

the pallet, lift the pallet from its storage rack, and bring the loaded pallet to the customer delays and complicates the retrieval sequence and storage sequence for vehicles awaiting to be stored.

[0006] In addition, all known prior art parking structures require large amounts of on-site installation of specialized fixed equipment within buildings built for the special purpose of enclosing the specific prior art system. The cost of this installed equipment and construction is not easily financed through conventional real property capital sources.

[0007] Finally, all known prior art automated parking structures involve highly specialized construction within buildings built to enclose the system of tracks, racks, and lifts required by the automated system. Prior art systems cannot easily be installed within existing garages. Despite fifty years of invention in the field of automated parking, most of the existing systems have not progressed far beyond their prototype stage. The reason such systems have not received market acceptance is the inherent inflexibility of the prior art systems.

[0008] What is needed is a system of semi-autonomous vehicle transporters linked through wireless connections and directed by a central computer which can be installed in existing garages as well as new garages constructed to optimize its benefits.

Summary of the Invention

[0009] The garage of the present invention comprises a single or multistory structure that houses a number of transporters which are low profile, self-powered, computer-controlled vehicle carriers that serve to move stored vehicles from place to place. The garage also includes access bays to enable vehicles to enter onto transporters and exit from transporters with ease. The garage preferably includes transporter stacker mechanisms and transporter recharging bays. In an embodiment of a multi-floor garage, the garage includes elevators or lifts to move transporters from floor to floor. An x-y coordinate system defines the garage space and enables the transporters and a central computer to communicate with each other regarding the positions of the transporters. The ability of the computer

to maneuver a large number of transporters simultaneously eliminates the need for fixed circulation lanes and results in the garage achieving a high vehicle density as well as efficient time and space utilization.

[0010] Other features and advantages of the present invention will become apparent after reviewing the detailed description of the preferred and alternative embodiments set forth below.

Brief Description of the Figures

[0011] **Figures 1A-1C** illustrate an arrival execution of the preferred parking system in accordance with the present invention.

[0012] **Figures 2A-2B** illustrate a retrieval execution of the preferred parking system in accordance with the present invention.

[0013] **Figures 3A-3B** illustrate simultaneously executed arrival and retrieval executions for two vehicles in accordance with the present invention.

[0014] **Figures 4A-4C** illustrate different views of the transporter in accordance with the present invention.

[0015] **Figures 5A** and **5B** illustrate different views of the preferred wheel assembly of the transporter in accordance with the present invention.

[0016] **Figures 6A** and **6B** illustrate different views of the preferred access bay assembly in accordance with the present invention.

[0017] **Figures 7A-7C** illustrate various transporter stacking assemblies in accordance with the present invention.

[0018] **Figure 8** illustrates an organizational diagram of the components of the preferred parking system in accordance with the present invention.

[0019] **Figure 9** illustrates an overhead view of an alternatively configured parking system in accordance with the present invention.

Detailed Description of the Present Invention

[0020] One aspect of the present invention is directed to an automatic parking system which has at least one parking level. The system comprises a plurality of transporters which are moveable in any direction about the parking level, wherein each transporter is adapted to hold a vehicle thereupon. The system also includes at least one central computer that is configured to wirelessly direct one or more of the transporters to move to a desired location to form at least one circulation path, such as an arrival path and/or a retrieval path.

[0021] Another aspect of the present invention is directed to an automatic parking system which has at least one parking level. The system comprises a plurality of transporters which are adapted to hold a vehicle thereupon, whereby each transporter is configured to be moveable in any direction along the one parking level. The system also comprises a central computer for wirelessly directing a selected transporter to a designated location.

[0022] Another aspect of the present invention is directed to a transporter adapted to hold a vehicle thereupon. The transporter moves the vehicle to one or more locations in a parking level. The transporter comprises a body and a plurality of wheel assemblies which are coupled to the body. Each wheel assembly is rotatable to any angle about an axis and is configured to move the transporter in any direction. The transporter comprises a computer that is coupled to the body and is configured to control operation of the wheel assemblies. The transporter further comprises at least one location sensor to determine the location of the transporter within the garage. The transporter further comprises a rechargeable battery for powering one or more components of the transporter. The transporter further comprises at least one proximity sensor, whereby the proximity sensor is configured to maintain the transporter at a predetermined minimum distance to an external object.

[0023] Another aspect of the present invention is directed to a parking system which is configured to selectively store or retrieve a vehicle on a parking level. The parking system comprises a central computer which is configured to select a parking space for the vehicle, wherein the central

computer wireless transmits a protocol for storing the vehicle in the parking space. The parking system comprises a transporter further comprising a body which is adapted to hold the vehicle thereupon and a plurality of wheel assemblies which are coupled to the body. The wheel assemblies are rotatable about an axis to any angle, wherein the wheel assemblies allow the transporter to move in any direction on the parking level. The transporter comprises an onboard computer which is coupled to the wheel assemblies and is configured to operate the wheel assemblies. The transporter also comprises a communication system which is configured to wirelessly receive the protocol from the central computer, wherein the onboard computer executes the received protocol to move the transporter to the parking space.

[0024] In yet another aspect of the present invention, a method of automatically moving a vehicle to or from a parking space. The method comprises selecting a protocol which depends on at least one predetermined factor. The method includes transmitting one or more instructions which relate to the protocol that is selected to an omni-directional transporter. The transporter then executes the instruction to move to a designated location in compliance with the selected protocol.

[0025] The above-mentioned aspects of the present invention preferably and alternatively include additional features and embodiments described as follows. The parking system further comprises a transporter tracking system, such as a transporter tracking system, which tracks the locations of each transporter. If the system is deployed on more than one floor, the parking system further comprises at least one lifting mechanism which vertically transports the transporter to a desired parking level, wherein the lifting mechanism is directed to the desired parking level by the central computer. The parking system further comprises at least one access bay which is configured to properly position an arriving vehicle onto the transporter as well as properly enable removal of an exiting vehicle from the transporter. The access bay includes at least one sensor located therein which measures the dimensions of the arriving vehicle. The parking system further comprises a storage device which is configured to store the transporters therein, wherein the storage device is directed to selectively accept and release one or more transporters by the central computer. The storage

mechanism is preferably configured to recharge the rechargeable battery of the transporter when the transporter is stored therein or on independent recharging docks that are provided. The parking system further comprises one or more entry stations which are configured to initially receive an arriving vehicle, whereby the entry stations include at least one device which measures dimensions of the arriving vehicle.

[0026] **Figure 1A** illustrates an overhead view of the preferred parking garage system 100 in accordance with the present invention. In particular, **Figure 1A** illustrates the access level 102 of the automated parking garage 100. The access level 102 of the present system 100 shown in **Figure 1A** preferably includes one or more access bays 112, a plurality of vehicle storage areas 106, one or more elevators or lifts 110, one or more transporter storage areas 114, and one or more circulation paths 116. The system 100 places each vehicle 99 which is to be parked on an omni-directional, self-propelled transporter 118 and uses a central computer 104 to designate an initial parking space for each transporter 118 by a protocol selected by the central computer. The system 100 includes a transporter tracking system 108 to wirelessly track the movement of the transporters 118 around the storage areas 106 and circulation paths 116 according to the protocol designated and selected by the central computer 104.

[0027] The access level 102 of the garage 100 shown in **Figure 1A** is preferably on ground level. In another embodiment, the access level 102 is above or below grade, in which the customer would reach the access level 102 by a vehicle ramp (not shown). In addition, the boundary of the garage 100 is enclosed by an outer wall. Preferably, the garage 100 is a multistory structure wherein additional vehicle storage areas 106 are located above and/or below the access level 102 (**Figure 1B**). Thus, vehicles 99 are transported to the underground and aboveground vehicle storage area via the elevators 110. Although **Figure 1A** shows parking of vehicles 99 on the access level 102, the garage 100 alternatively does not store cars on the access level 102 if such space would be more valuable for other uses, such as retail and lobby space for offices or apartments. It should be noted that although

the garage 100 shown in **Figure 1A** is substantially rectangular, the garage 100 is alternatively any other shape and is able to operate efficiently in any other shaped land parcel as shown in **Figure 9**.

[0028] As shown in **Figure 1A**, the present garage 100 includes a central computer 104 preferably located in the garage 100. Although the central computer 104 is shown next to the access bays 112, it is contemplated that the central computer 104 is located anywhere else in the garage 100. Alternatively, the central computer 104 is located outside of the garage 100. Although one central computer 104 is described herein, each parking level 102, 202 (**Figure 1B**) alternatively has its own designated central computer which plans, controls and manages the devices on that particular level 102, 202 (**Figure 1B**). In addition, the system 100 preferably utilizes a transporter tracking system 108 which wirelessly tracks each transporter 118 and communicates the information to the central computer 104. Although the transporter tracking system transceivers 108 are shown in the corners of the garage 100, the transceivers 108 are positioned in any appropriate location inside or outside of the garage 100.

[0029] The access level 102 shown in **Figure 1A** includes three access bays 112 and access bay entries 14, three elevators or lifts 110 and four transporter stacking mechanisms 114. It is apparent to one skilled in the art that any number of access bays 112, access bay entries 14, elevators or lifts 110, and stackers 114 are contemplated and are dependent on the physical garage site as well as the type and amount of parking demand contemplated. It is also apparent to one skilled in the art that the access bays 112, access bay entries 14, elevators 110 and stacking mechanisms 114 are alternatively positioned at any other location with respect to the garage 100. For instance, some access bays 112 and elevators 110 are alternatively placed on opposite ends of the garage 100 (not shown) such that vehicles are able to enter and exit the garage from any or all sides of the garage 100. Alternatively, the garage 100 does not include elevators 110, access bays 112 and/or transporter stacking mechanisms 114. It should be noted that the designation of the storage areas 114 and circulation path 116 does not imply that the storage area cannot become part of a circulation path.

[0030] **Figure 1A** illustrates the garage 100 geographically located adjacent to a garage entrance lane 10. In one embodiment, the garage entrance lane 10 is a road dedicated for the entry and exit of vehicles from the garage 100. In another embodiment, the garage entrance lane 10 is a municipal roadway which vehicles turn off of when entering the garage 100 or turn onto when leaving the garage 100. It is preferred that the garage entrance lane 10 includes one or more entry stations 12, although only one entry station 12 is shown in **Figure 1A**. Alternatively, the system 100 does not include an entry station 12 in the adjacent roadway 10. In another alternative embodiment, the system 100 does not include a roadway located adjacent to the garage 100, wherein the driver simply pulls her vehicle up to the access gates 14.

[0031] The arrival execution and operation will now be discussed in relation to **Figures 1A - 1C**. A driver customer wishing to park her vehicle 99 arrives at an entry station 12, whereby the vehicle 99 is stopped at the lift arm or similar device at the entry station 12. One or more sensors (not shown) are preferably located at the entry station 12. While the vehicle 99 is waiting at the lift arm 12, the sensors (not shown) positioned in the pavement (not shown) weigh the load of the vehicle 99 and determine the dimensions of the vehicle's 99 wheelbase, which is the distance between the front and rear wheels. In addition, the sensors (not shown) measure the wheel track of the vehicle 99, which is the width distance between the wheels. In addition, the sensors (not shown) measure whether the height of the vehicle is in compliance with the garage's criteria. Alternatively, the sensors (not shown) are located in the access bays 112 instead of the entry gate 12. Preferably, the sensors (not shown) then make a determination whether the vehicle 99 is compliant with the garage's criteria. Alternatively, the sensors (not shown) transmit the measured data to the central computer 104, whereby the central computer 104 then makes the determination whether the vehicle 99 is compliant with the garage's criteria.

[0032] If the weight distribution and/or dimensions of the vehicle 99B are outside of the garage's criteria, the customer is informed of the noncompliance through an electronic signboard or similar graphic means located at or near the entry gate 12. The customer is then instructed to leave the

garage according to a designated route to avoid disruption to waiting customers. The lift arm at the entry gate 12 lifts and allows the vehicle 99B to proceed past the entry gate 12, but does not allow the vehicle to proceed to the access bay gate 14. Instead, the noncompliant vehicle 99 proceeds along the entry lane 10 back into traffic.

[0033] During the entry execution, the customer is preferably asked to provide an expected departure time. While this feature is not a necessary aspect of the present invention, the expected departure time enhances system performance. If the weight distribution and/or dimensions of the vehicle 99 comply with the garage's criteria, the customer receives a coded ticket from the lift arm 12 which contains an identifying code number for the vehicle 99B as well as the vehicle's 99B time of arrival. Preferably, the sensors (not shown) at the entry station 12 transmit the weight distribution and/or dimensions of the vehicle 99 as well as other information to the central computer 104. The central computer 104 incorporates the measurement information into choosing the protocol for the vehicle 99 as well as transmitting the information to the access bays 112, transporters 118 and lifts 110 as discussed below. The lift arm 12 is then lifted and the customer is instructed to proceed to a designated access bay gate 14. In one embodiment, the designated access bay gate 14 is indicated by number on the electronic signboard (not shown). Alternatively, the designated access bay gate 14 is indicated by number on the ticket itself or some other means.

[0034] As stated above, the central computer 104 preferably creates a protocol for loading the vehicle 99B onto the transporter 118B and moving the transporter 118B to an appropriate parking space. The central computer 104 transmits the storage protocol to the transporter 118B, as well as to the elevators 110, other transporters 118 as well as other devices involved in the particular storage execution for the vehicle 99B.

[0035] The term protocol refers to a partial set or complete set of instructions sent to a selected transporter 118, as well as other transporters and devices, such as elevators 110, access bays 112 and stackers 114 which are involved in the arrival and/or retrieval execution of the vehicle 99.

Thus, the term protocol, and instruction or instructions are used interchangeably in the present description. The central computer 104 preferably separates the protocol into a number of instruction sets which are specific to each selected device in efficiently creating an arrival or retrieval circulation path. For example, the protocol instructs a transporter 118 to move out of the access bay 112 at a specified time and travel to a position in front of an elevator 110 while simultaneously calling the elevator 110 and relocating transporters 118 on the destination floor 202 to create a circulation arrival path. The instruction set for the subject transporter 118 instructs the transporter 118 to move to the position in front of the elevator 110 and await a specified time or a signal from the central computer 104 to proceed to the elevator 110. The instruction set for the elevator 110 instructs the elevator 110 to move to the designated floor at a specified time. The instruction set also instructs all transporters on the destination floor to move to a desired location to create the arrival or retrieval circulation path. The instruction set for the subject transporter 118 on the destination floor instructs the transporter 118 to move a specified location to create the arrival path.

[0036] As shown in **Figure 1A**, the access bay 112B is assigned to receive the incoming vehicle 99B. In one embodiment, the assigned transporter 118 is already positioned within the access bay 112B associated with the designated access bay gate 14 when the vehicle 99B is pulling into the access bay 112B. Alternatively, the assigned transporter 118 is retrieved from the transporter stacking mechanism 114, whereby the assigned transporter 118 propels itself to the access bay 112 associated with the designated access bay gate 14 discussed above. As shown in the example in **Figure 1A**, the transporters 118A and 118B are already positioned within the respective access bays 112A, 112B. Access bay 112C does not contain a transporter, whereby the loaded transporter 118C is shown to be moving into access bay 112C for retrieval.

[0037] Access bay entries 14 located in front of the access bays 112 ensure that the arriving vehicle 99 enters the designated access bay. In particular, once the vehicle 99B drives up to the access bay entry 114, the customer preferably inserts the card provided at the entry gate 12 into the machine to ensure that the vehicle 99B is entering its designated access bay 112B. Alternatively, any other

appropriate method or device for identifying the correct vehicle is employed at the access bay entry 14. After it is determined that the vehicle 99B is entering its designated access bay 112B, the arm at the entry 14 is lifted and the customer pulls into the access bay 112B. The customer preferably drives the vehicle 99B forward into the access bay 112B and is loaded on top of the waiting transporter 118B, until the vehicle's 99B wheels engage the access bay's wheel stop mechanism 606 (**Figures 6A-6B**), which is discussed in more detail below.

[0038] Indicator lights, electronic signboards and other graphics in or around the access bay 112 instruct the customer to put the vehicle 99 in park, turn off the engine, set the parking brake, lock the vehicle and exit the access bay 112B. The access bay 112 preferably includes a gate or lift arm leading to the interior of the garage 100 which remains closed until it is confirmed that the customer and any passengers have vacated access bay 112. The gate prevents intruders from entering into the interior parameter of the garage 100. The gate opens once it is confirmed that the access bay 112 has been vacated and the transporter 118 is about to execute its instructions. During the confirmation process, the access bay 112 is preferably subject to video surveillance by a remote operator available to assist the customer through intercom contact. At this time, the exterior condition of the vehicle is preferably photographed for future reference. Sensors present in the access bay 112B confirm that the vehicle 99B and access bay 112B are clear of persons and/or obstructions. The central computer 104 then issues instructions to the access bay 112B to retract the wheel stop 606 (**Figures 6A-6B**) and tire guides 608 (**Figures 6A-6B**) to allow the transporter 118B and vehicle 99B to proceed with the storage execution.

[0039] The present garage 100 is preferably mapped with a two-dimensional coordinate system indicating the dimensions of the enclosed space as well as any fixed elements within the space, such as columns and walls. In one embodiment, the onboard computer 406 (**Figure 4A**) on each transporter 118 interprets sensor data and wirelessly relays information about the transporter's 118 position and movement to the transporter tracking system on a real time or periodic basis. The transporter tracking system assembles the information provided by all of the tranporters 118 into a

dynamically changing map of the garage floors. Position sensor data alternatively includes, but is not limited to, radio frequency triangulation, laser, optical or ultrasonic distance measurement, embedded wire or surface-based optical identification, camera based object identification and inertial guidance, or any other appropriate method. Alternatively, a grid of stationary sensors detects the position of the transporters 118 based on radio frequency identification transmission, and this information is communicated directly to the transporter tracking system which maps the position of the mobile transporters. This information is then utilized by the central computer 104 in generating protocols to accomplish vehicle storage and retrieval. It should be noted that any other appropriate method of tracking the transporters and other devices is contemplated by one skilled in the art.

[0040] Referring back to the present example in **Figures 1A** and **1B**, the protocol sent by the central computer 104 instructs the transporter 118B to go to parking spot 204 on a different parking level 202. The central computer 104 selects the elevator 110A and instructs the transporter 118B to proceed to elevator 110A. Simultaneously, the central computer 104 instructs the elevator 110A to be ready to receive the transporter 118B. In the present example, the central computer 104 designates elevator 110A, because the designated parking space 204 (**Figure 1B**) is geographically closest to the elevator 110A. Alternatively, the central computer 104 selects any of the other elevators 110B, 110C depending on several factors including, but not limited to, elevator availability, time of retrieval, and proximity to the selected destination. Executing the instructions contained in the protocol, the loaded transporter 118B propels forward out of the access bay 112B enough to clear the access bay 112B and then stops. In one embodiment, such as during a peak arrival period, once the transporter 118B vacates and clears the access bay 112B, the central computer 104 instructs an empty transporter 118 to move into position in the access bay 112B to receive the next arriving vehicle 99. In another embodiment, the central computer 104 balances the demand for arrival (i.e., transporter waiting) with retrieval (empty access bays) according to time-of-day experience.

[0041] The present system 100 preferably utilizes standard freight-type elevators or lifts 100 to carry the transporters 118. The elevators 110 operate under the control of the central computer 104

and preferably report position information to the central computer 104. It is apparent to one skilled in the art that the elevators 110 alternatively do not have doors or inside walls and merely have a skeleton structure with a platform to hold the transporter 118 thereupon.

[0042] **Figure 1B** illustrates the designated floor 202 in which the transporter 118B has been instructed by the central computer 104 to park in the present example. The floor 202 is divided into an array of parking locations or spaces suitable to the dimensions of the transporters 118. Preferably, there are no guide tracks or dedicated circulation lanes on the floor 202. While the common size of vehicles would suggest that the array of parking spaces would be regular throughout, the invention is based on an x-y coordinate grid of location points and does not require that a uniform parking module be maintained. For instance, the present garage 100 is alternatively designed to accommodate over-standard, standard and/or subcompact size vehicles 99 in different size storage locations.

[0043] Upon arrival to the designated floor 202, the elevator stops and its doors open, and the transporter 118B moves onto one circulation path area 216, shown in **Figure 1B** as the area in front of the elevators 110. As stated above, the transporter 118B is instructed by the central computer 104 to travel to the parking space 204. The circulation path selected by the central computer 104 in the present example is shown by the arrows in **Figure 1C**. As shown in **Figure 1B**, the movements of the other transporter 118B are coordinated with the movements of the selected transporter 118 to store the selected transporter, whereby all movements are directed by the central computer 104 through specific protocols sent to each of the selected transporters 118.

[0044] The flexibility of the present system 100 is based on the ability of the central computer 104 to coordinate the movement of each transporter independently 118 of other transporters 118 to create whichever dynamic circulation path or paths are suitable for storage and/or retrieval of a particular vehicle 99. In operation, the circulation path is dynamic or effectively "floats" along the parking floor to where it is needed to provide efficient access for storage and/or retrieval for one or more vehicles 99. Although the example in **Figure 1B** illustrates a simple execution of transporter

movements, it is apparent to one skilled in the art that more complex executions of movement may result from increasing the number of vehicles 99 stored on a floor. Similarly, simpler executions of transporter movements are apparent to one skilled in the art by decreasing the number of vehicles 99 stored on a floor. The coordination of this execution causes each of the selected transporters 118 to execute the unique protocols provided by the central computer 104 defining the timing, direction, speed and extent of movement for each transporter 118. Each transporter 118 preferably relays its position to the transporter tracking system periodically or in real time to confirm that the instructed movements have been executed and have proceeded according to plan. In addition, each transporter 118 preferably utilizes its proximity to prevent any collisions or mishaps from occurring during the execution.

[0045] For clarity in explaining the examples, the level 202 is mapped into several areas or sectors comprising a series of rows and columns, whereby the columns are designated as letters A-H and the rows are designated as numbers 1-14. It should be noted that any number of rows and columns are alternatively contemplated. For instance, the designated parking spot 204 for the loaded transporter 118B is shown in **Figure 1B** is located in area or sector F3.

[0046] In the present example in **Figure 1B**, the central computer 104 instructs the two transporters 118 in parking spots B3 and B4 to move in the -Y direction to parking spots B11 and B12, respectively, as shown by the arrows. The movement of the transporters 118 away from parking spots B3 and B4 provide a partial arrival circulation path for the transporter 118B. Once the transporters previously in areas B3 and B4 move in the -Y direction past the elevator 110A, the transporter 118B preferably moves from the elevator 110A into space B6 and stops. The transporter 118B then rotates its wheels and propels itself in the Y direction to sector B3.

[0047] It is preferred that simultaneous with this activity, the five transporters in parking spots C3-C7 move one space in the -Y direction, as shown by the arrows. As shown in **Figure 1C**, the same rows of transporters in columns D and E perform the same maneuver. As a result, the transporters 118 initially in row 7 of columns C, D and E, move one parking space into the open spaces

203, 206, and 208, respectively. In addition, the transporters previously in row 3 of columns C, D, and E move one space in the -Y direction into row 4 of columns C, D and E. As a result, the transporters previously in C3, D3 and E3 vacate the sectors 210, 212 and 214 (**Figure 1C**), thereby creating the remaining portion of the arrival circulation path for the transporter 118B. The transporter 118B then preferably propels forward along row 3 toward the parking space 204. The circulation path taken by the transporter 118B is shown in **Figure 1C**. It should be noted that although one circulation path is created in the present example, the system 100 is able to create any number of circulation paths to store and/or retrieve one or more vehicles at a particular time.

[0048] In one embodiment, the transporter 118B communicates to the central computer 104 that it has reached its destination 204. Alternatively, the transporter 118B does not communicate to the central computer 104 that it has reached its destination 204 whereby the transporter tracking system 108 notifies the central computer 104. Depending on the protocol selected by the central computer 104, some or all of the selected transporters 118 which were moved during the example arrival execution are instructed to return to their prior parking spaces. Alternatively, the transporters 118 do not return to their prior parking spaces.

[0049] Although one arrival circulation path is described in relation to **Figures 1B** and **1C**, it is apparent to one skilled in the art that any number of alternative arrival paths are able to be generated and executed by the present system 100 to deliver the transporter 118B to parking area 204. The central computer 104 preferably applies present or stored circulation path algorithms and protocols to review a large number of possible circulating paths. For instance, transporters located in positions F4-F7 could be moved in the -Y direction to create a vacant space at location F7 at which to share the vehicle 118B. Alternatively, vehicle 118 B could be stored in space B12. The criteria for selecting a storage location include, but are not limited to, factors such as minimizing transporter movements, minimizing elapsed time, and locating transporters for ease of retrieval.

[0050] It should be noted that although the preceding example is described as a set of discrete steps, the preceding execution preferably occurs simultaneously or substantially simultaneously to the extent that no collisions occur and the transporter 118B effectively reaches its assigned destination. Preferably in the above example, the selected transporters 118 traverse to their instructed positions on the floor 202 before the transporter 118B reaches the floor 202. The arrival circulation path is thus preferably created and cleared for the transporter 118B by the time the transporter 118B arrives at the destination floor 202. This reduces the amount of time to deposit the transporter 118B in its designated parking space 204. Alternatively, the selected transporters 118 traverse to their instructed positions on the floor 202 after the transporter 118B reaches the floor 202 or at any other time. It should be noted that the same applies to the retrieval execution below.

[0051] An example of the retrieval of a vehicle execution will now be discussed in relation to **Figures 2A-2B** for the loaded transporter 118B parked in parking space 204. As shown in **Figures 2A-2B**, the selected transporters 118 which were moved during the arrival execution in **Figures 1B** and **1C** are shown positioned in their original locations as in **Figure 1B**. In retrieving the vehicle 99B, the customer arrives at a payment kiosk or payment window. As the coded information on the customer's entry ticket is processed for payment purposes, the central computer 104 creates a retrieval protocol that creates a retrieval circulation path to efficiently retrieve the requested transporter 118B.

[0052] In the present example, the central computer 104 transmits the instructions related to the retrieval protocol to the transporter 118B in parking space 204 as well as the other involved devices. The retrieval circulation path selected by the central computer104 and to be taken by the transporter 118B is shown by the arrows in **Figure 2B**. The retrieval execution is managed by the central computer 104, whereby the central computer 104 wirelessly communicates the instructions to each of the selected transporters 118, the timing, direction, speed and extent of movement which each transporter 118 is to execute. Each selected transporter 118 relays its position to the transporter tracing system periodically or in real time to confirm that the instructions to that particular transporter

118 have been executed and completed according to plan. In addition, the proximity sensors in each transporter 118 preferably prevent any collisions or mishaps from occurring during the execution.

[0053] As shown in **Figure 2A**, the central computer 104 selects the two transporters in parking spots B3 and B4 and instructs the transporters to move in the -Y direction to parking spots B11 and B12, respectively, as shown by the arrows. Preferably at the same time, the five transporters in parking spots C3-C7 moves one space in the -Y direction, as shown by the arrows. In addition, the same rows of transporters in columns D and E perform the same maneuver. As a result, the transporters initially in row 7 of columns C, D and E move one parking space into the open spaces 203, 206, and 208, respectively. In addition, the transporters previously in row 3 of columns C, D, and E move one space in the -Y direction into row 4 of columns C, D and E. As a result, the transporters previously in C3, D3 and E3 vacate the sectors 214, 212 and 210, thereby providing the remaining portion of the retrieval circulation path for the transporter 118B. **Figure 2B** illustrates the resulting circulation path. It should be noted that although one circulation path is created in the present example, the system 100 is able to create any number of circulation paths to store and/or retrieve one or more vehicles simultaneously at a particular time.

[0054] The transporter 118B then preferably propels forward in the -X direction along row 3 toward sector B3. Once the transporter 118B reaches the sector B3, the transporter 118B turns its wheels ninety degrees and proceeds perpendicularly in the -Y direction along row 3 to the area in front of the elevator 110B. Preferably, the elevator 110B is already instructed by the central computer 104 to be called to the floor 202. Once the transporter 118B reaches the elevator, the transporter 118B turns its wheels ninety degrees and proceeds forward into the elevator 110B.

[0055] The elevator 110B transports the transporter 118B to the access level 102. Once the elevator 110B and the transporter 118B arrive at the access floor 102, the transporter 118B exits the elevator 110B and proceeds to the designated access bay 112. Preferably the transporter 118B rotates 180 degrees at an instructed location to enable the customer to depart the access bay 112 into

the adjacent roadway without having to perform a backing maneuver. Alternatively, the rotation of the transporter 118B is undertaken at one or more points in the storage and/or retrieval executions, depending on factors including, but not limited to, peak versus non-peak timing and availability of adequate rotating space at specified locations in the garage 100. The rotation of the transporter 118B is accomplished by instructing the front and rear wheel assemblies 412 to set at an appropriate angle and powering the front wheel assemblies. The instructions to rotate are preferably included in the protocol sent by the central computer 104, whereby the transporter's onboard computer 406 executes and manages the rotation task. Alternatively, the transporter 118B performs the rotation task during the arrival execution instead of the retrieval execution. In another embodiment, the transporter 118B does not perform a rotation task in the arrival or retrieval execution.

[0056] Once the transporter 118B is properly secured in the designated access bay 112, the customer is notified by an electronic sign or other means that the vehicle 99B is ready for pick up. The customer is then allowed to enter the access bay 112, retrieve the vehicle 99B, and exit the access bay 112 through the access bay gate 14. During retrieval peaks, the central computer 104 preferably moves the empty transporters 118 to the storage stackers 114 to clear the access bays 112 for receipt of transporters holding other vehicles to be retrieved.

[0057] **Figures 3A** and **3B** illustrate simultaneously executed arrival and retrieval executions involving two vehicles. As shown in **Figures 3A** and **3B**, the transporter 118B discussed above in relation to **Figures 1A-2B** is shown in location B3, having been partially retrieved from parking space 204. In addition, the transporter 118D in the elevator 110C to be parked in parking space 222 is located in area F12 (reference numeral 222). The arrival circulation path for transporter 118D is shown by the arrows in **Figure 3B**. For brevity, the transporter 118B is retrieved from location F3 and is shown in **Figure 3A** proceeding along the retrieval circulation path described above in **Figure 2B** to the elevator 110B. The details of this execution are discussed above in relation to **Figures 2A** and **2B**.

[0058] Preferably, as the transporter 118D is transported to the level 202 in the elevator 110D, the transporters 118 which were moved to create the retrieval circulation path of transporter 118B are repositioned by the protocol transmitted by the central computer 104 to create the arrival circulation path for the transporter 118D. In the present example, the protocol transmitted by the central computer 104 instructs the transporters 118 in areas F9, F10, and F11 to move in the Y direction one parking space to open the parking space F12, 222. Thus the transporters 118 previously in areas F9-F11 are moved to areas F8-F10.

[0059] To create the remaining portion of the arrival circulation path (areas C11-E11), the protocol sent by the central computer 104 also instructs the column of transporters 118 in column E to move in the Y direction. In the present example, the central computer 104 determines that the parking space 204 is no longer needed and is able to be filled with one of the transporters 118 which are being moved to create the arrival circulation path for the transporter 118D. Therefore, as shown in **Figure 3A**, the central computer 104 instructs the transporter in area E4 to move one space in the Y direction and then one space in the X direction into the parking space 204. Similarly, the central computer 104 instructs the transporter in area D4 to move one space in the Y direction and then one space in the X direction into the parking space 210. The central computer 104 also instructs the transporter in area C4 to move one space in the Y direction and then one space in the X direction into the parking space 212.

[0060] The central computer 104 instructs the transporters in the areas E5-E11 to each move in the Y direction one space to open the area E11, 224 (**Figure 3B**). Additionally, the central computer 104 instructs the transporters in the areas D5-D11 to each move in the Y direction one space to open the area 226 (**Figure 3B**). The central computer 104 also instructs the transporters in the areas C5-C11 to each move in the Y direction two spaces to open the parking spots 220 and 228 (areas C10 and C11, respectively). As shown in **Figure 3B**, the transporters instructed to move are shown in their new parking spots, and the arrival circulation path is cleared for the transporter 118D to park in space 222, as shown by the arrow.

[0061] In one embodiment, the above-described execution occurs substantially simultaneously. Referring back to **Figure 3A**, it is apparent that the transporters moving in the Y direction and then the X direction into parking spots, 204, 206 and 208 will take a longer amount of time to perform their maneuvers than the other selected moving transporters. This is due the transporters having to stop and turn their wheel assemblies ninety degrees to move in the X direction. Therefore, in one embodiment, the central computer 104 instructs the remaining transporters to wait to move until the above-mentioned transporters have turned their wheel assemblies and moved into the parking spots, 204, 206 and 208 Alternatively, the central computer 104 instructs the remaining transporters to move simultaneously with the above-mentioned transporters, but at a slower speed to maintain proper distance with those transporters 118. The proximity sensors on each of the transporters 118 ensure that sufficient distance is maintained.

[0062] It should be noted that the preceding example is a relatively complex execution and, the present system 100 would preferably select a different space to store the transporter 118D or a simpler execution protocol to park the transporter 118D. However, the preceding example illustrates the concept of the "floating" or dynamic circulation path and versatility and flexibility of the present system 100. The preceding example also illustrates the limitless possibilities of arranging the transporters 118 in different configurations to efficiently park and retrieve vehicles 99. Therefore, the preceding example is in no way limiting to the operation of the present invention.

[0063] The specifics of each component of the present system will now be discussed in detail. The central computer 104 of the present invention preferably performs both the planning and management functions for the smooth operation of the automated garage 100. In particular, the central computer 104 communicates with the transporter tracking system as well as each transporter 118 and other devices. The central computer 104 is thus informed of the status of each transporter 118 in the garage 100 at all times. Each transporter 118 and device preferably has a unique ID which is used by the transporter tracking system 108 as well as the central computer 104 to identify, track and communicate with each transporter 118 and device. An organizational schematic of the system is

shown in **Figure 8**. Thus, the central computer 104 is also informed of the status of the entry gates 12, elevators 110, access bays 112 as well as access gates 14 and the transporter stackers 114.

[0064] The planning function of the central computer 104 involves the creation of transporter movement protocols or instructions based on user requests or in anticipation of user requests. The movement protocols include selecting a parking space and generating a circulation path to deliver vehicle 99 to that parking space. In addition, protocols involve executing a series of movements involving the designated transporter 118, other selected transporters 118 and certain devices to move the vehicle along the circulation path. The logic of the central computer 104 in generating a protocol is preferably based on a process of generating several possible protocols and scoring each protocol according to a management controlled criteria. The protocols are generated anew or are retrieved from a stored database of previously generated protocols. The protocol for a newly arrived vehicle is dependent on the status of the garage 100 at the time of arrival as well as information from entry sensors or provided by the user at the time of arrival. The central computer 104 then selects the most favorable protocol based on one or more factors. Such factors include, but are not limited to, how long the vehicle will be stored in the garage; how long other vehicles in the garage will be stored; whether the customer is transient, monthly or VIP, availability of parking spaces in the garage; and size and weight of the vehicle. For instance, if the expected departure time of vehicle 99 is relatively later than many of the already stored vehicles 99 in the garage 100, the central computer 104 will preferably choose a parking space which is located further away from the elevators 110 or access bays 112 than the earlier departing vehicles 99. Additionally, a monthly customer or frequent parker code would cause the central computer 104 to generate an appropriate protocol to store the vehicle 99 in a quick access location. Alternatively, an arriving customer could choose a "late pick-up option" which would instruct the central computer 104 to store the vehicle 99 in a location furthest away from the elevators 110 or access bays 112.

[0065] As stated above, the status of the garage 100 at the time of arrival or request for retrieval also affects the protocol selected by the central computer 104. For instance, a vehicle 99

arriving during an outgoing peak might be temporarily stored in a waiting position to avoid its storage protocol from interfering with any outgoing activity. Once the outgoing peak of transporters 118 has passed, the central computer 104 generates a new protocol to store the waiting vehicle 99 or alternatively authorizes the waiting transporter to proceed.

[0066] Once a protocol is selected, the protocol preferably includes an instruction set that is wirelessly transmitted to each transporter and device participating in the particular task In one embodiment, the instruction set is time-based. Alternatively, the instruction set is authorized-based, whereby the devices are provided with their unique instruction sets but do not execute their instructions until authorized by the central computer 104. Alternatively, the instruction set is a time-based and authorized-based combination. The central computer 104 preferably communicates the protocols to each of the selected devices simultaneously. In one embodiment, each of the devices confirm receipt of the instructions back to the central computer 104. In another embodiment, the devices do not confirm receipt of the instructions back to the central computer 104. Each of the devices which receive the instructions execute the instructions at the time specified or upon authorization by the central computer 104. In the preferred embodiment, each participating device notifies the central computer 104 after successfully completing each step in its instruction set. Alternatively, the transporter tracking system additionally tracks each participating device as confirmation that the step has been completed.

[0067] The central computer's 104 management function involves utilizing the transporter tracking system 108 to preferably maintain a real-time or periodically updated three-dimensional model of the garage 100. The management function also preferably takes into account the speed, direction and distance of each moving transporter 118. The central computer 104 utilizes the model as a basis for planning and selecting a protocol as well as to monitor the status of each transporter and device in relation to one or more already selected protocol plans. The monitoring activity includes comparing the status and position of each reporting transporter 118 with the selected protocols and identifying present and future noncompliant devices and/or events. For instance, the management function of the central computer 104 will foresee a potential collision with two transporters 118 from the operational

information provided by either or both transporters 118. It is preferred that the central computer 104 simultaneously obtains diagnostic information regarding mechanical and electronic functions and battery capacity from transporters and/or devices and takes appropriate action or notifies a human supervisor. It should be noted that the central computer 104 alternatively performs additional tasks and is not limited to the description provided above.

[0068] **Figures 4A-4C** illustrate several different views of the transporter 118 in accordance with the present invention. As stated above, each vehicle 99 entering and exiting the garage 100 is placed on a transporter 118 which is a self-powered and omni-directional platform that transports the vehicle 99 to any instructed location in the garage 100. As shown in **Figure 4A**, the transporter 118 includes a body 400 preferably having a top bearing plate 402 on top of which the vehicle 99 is supported. The top bearing plate 402 is preferably surfaced with a non-slip finish to stabilize and prevent slippage of the vehicle 99. The body 400 of the transporter 118 is preferably symmetrical along both axes and is designed to operate indifferent to the orientation of the vehicle's front end and back end.

[0069] The transporter 118 includes a wireless transceiver communication system 406 by which the transporter 118 communicates with the central computer 104 and the transporter tracking system 108. The transporter 118 includes four independently rotatable wheel assemblies 412 which are preferably driven by separate electric motors. The transporter 118 includes an onboard computer 418 (**Figure 4C**) which manages and controls the operation of the transporter 118 with any external objects. The transporter 118 also preferably includes a set of proximity sensors 414 located on each side of the transporter 118 which provide a safeguard in preventing collision of the transporter 118 with any external objects. The transporter 118 also preferably includes a gyroscope or similar orientation measurement device (not shown) which provides information to the onboard computer 418 regarding the orientation of the transporter 118. The transporter 118 is preferably equipped with one or more batteries 416 (**Figure 4C**) which powers the computer 418, sensors 414, wheel assemblies 412, transceiver 406 and other electronics onboard. This allows the transporter 118 to operate within the

garage 100 without creating any pollution. The batteries 416 are preferably rechargeable at recharging docks included in the stacking devices 114 (**Figures 7A-7C**) or at other locations within the garage 100. Alternatively, the transporters 118 are electrically powered but do not have batteries.

[0070] The onboard computer 418 preferably operates and controls every aspect of the transporter 118. The onboard computer 418 is preferably located in the undercarriage of the transporter body 400 as shown in **Figure 4C**. Alternatively, the computer 418 is located elsewhere on the body 400. The onboard computer 418 is coupled to the wireless transceiver 406, whereby the computer 418 processes information received by the transceiver 406 as well as generates information to be sent by the transceiver 406. The onboard computer 418 is also coupled to each of the wheel assemblies 412, whereby the computer 418 controls the various propulsion, braking, steering and diagnostic systems of the wheel assemblies 412 individually or collectively. In addition, the onboard computer 418 is coupled to the proximity sensors 414, battery power sensors, directional sensor and other sensors which provide information used by the onboard computer 418 and central computer 104 to manage the operation of the transporter 118.

[0071] The onboard computer 418 processes automated logic and sensory data sent to and received from the central computer 104 and transporter tracking system 108 for navigating the transporter 118. The wireless communication system 406 communicates with the central computer 104 to effectively navigate the transporter 118 as well as communicate diagnostic and operational information regarding the transporter 118 to the central computer 104. It is preferred that the transporter's communication system 406 communicates with the central computer 104 and transporter tracking system 108 using radio frequency communication protocols. Alternatively, the communication system 406 communicates with the central computer 104 using any other appropriate wireless communication technique. As stated above, the central computer 104 is provided measurement information of the vehicle 99 when the vehicle 99 arrives at the garage 100. Preferably, the protocol instructions provided to the transporter 118 take into account the weight and mass of the vehicle such that the vehicle's characteristics do not adversely affect the transporter's 118 performance.

[0072] As stated above, the transporter 118 communicates its position to the transporter tracking system utilizing the communication system 406. Preferably, the transceiver 406 provides precise coordinates of the transporter's 118 four corners based on on-board sensor data on a periodic or real-time basis to the transporter tracking system 108 and the central computer 104. Position sensor data alternatively includes, but is not limited to, radio frequency triangulation, laser, optical or ultrasonic distance measurement, embedded wire or surface-based optical identification, camera based object identification and inertial guidance, or any other appropriate method. Alternatively, a grid of stationary sensor detects the position of the transporters 118 based on radio frequency transmission and provides the data to the central computer 104.

[0073] Several factors, including but not limited to, misalignment of the wheel assemblies 412, improperly distributed weight, and variances in the surface floor of the garage 100 may cause the transporter to slightly veer off course in executing the protocol. Thus, the onboard computer 418 manages the operation of the transporter 118, while the transporter 118 is moving, to ensure that the transporter maintains and is in compliance with its projected course associated with the protocol. In one embodiment, the onboard computer 418 monitors and compares the movement of the transporter 118 with the transporter tracking system 108, as the transporter 118 is moving, to ensure that the transporter 118 is moving in a straight line, properly rotating, properly making a turn or merely staying on course. Alternatively, or additionally, the onboard computer 418 is coupled to sensors in the individual wheel assemblies 412, whereby the wheel assemblies 412 relay positional information to the onboard computer 418 to ensure that the transporter 118 is staying on course. Alternatively, the onboard computer 418 uses any other means or methods to ensure that the transporter 118 stays on course with the instructed protocols. In the event that the transporter 118 veers off course, the onboard computer 418 adjusts the steering, speed or any other desired parameters to ensure that the transporter 118 moves back onto the projected course instructed in the protocol. Alternatively, or in addition to, the onboard computer 418 relays necessary information to the central computer 104, whereby the central computer 104 provides new or revised protocol instructions.

[0074] The onboard computer 418 also preferably manages the proximity sensors 414 of the transporter 118 as well as communicates information pertaining to the sensors to the central computer 104. In the event that any proximity sensors 414 sense that the transporter 118 is too close to another object, the sensor(s) will relay the appropriate signal to the onboard computer 418. The onboard computer 418 will then undertake immediate corrective action and communicate this information to the central computer 104. The central computer 104 will then modify the protocol for that transporter 118 as well as any other transporters and/or devices, if needed, such that a collision will be avoided. In one embodiment, the onboard computer 418 collects diagnostic data concerning available battery power, motor performance and other information from onboard sensors and transmits such data through the communication system to the central computer 104.

[0075] **Figure 5A** illustrates a side view of the preferred wheel assembly 412. **Figure 5B** illustrates an underside view of the preferred wheel assembly 412. The wheel assemblies 412 are preferably operable independent of one another and are independently controlled by the onboard computer 418. An organizational schematic of the wheel assemblies and the onboard and control computer shown in **Figure 8**. As shown in **Figure 5A**, the wheel assembly 412 is shown coupled to the body 400 of the transporter 118. The wheel assembly 412 preferably includes a stationary gear 502, a rotatable base 504, a wheel support 506 having an axle 512, a steering motor 508, a set of tires 500 each coupled to a wheel 510, and one or more drive motors 514 coupled a drive gear 516. It is apparent to one skilled in the art that the wheel assembly 412 is not limited to the configuration shown and described herein, and any other appropriate configuration is alternatively contemplated to provide a rotatable wheel assembly capable of allowing the transporter 118 to move in any direction.

[0076] The stationary gear 502 is preferably mounted to the underside of the transporter body 400 by one or more bolts (not shown). The rotatable base 504 is preferably coupled to the body 400 by an appropriate means and is rotatable about the axis 98 in a 360-degree fashion. The rotatable base 504 is preferably able to smoothly rotate about the axis 98 by utilizing the bearings 522 located between the rotatable base 504 and the stationary gear 502. Alternatively, any other appropriate

means is employed to achieve smooth rotation of the rotatable base 504. Preferably the rotatable base 504 includes a pair of wheel supports 506 which extend downward therefrom, whereby the axle 512 is coupled to the wheel supports 506, as shown in **Figure 5B**. The wheels 510 are coupled to the axle 512 and the tires 500 are coupled to the wheels 510.

[0077] The steering motor 508 is preferably mounted to the underside of the rotatable base 504. The steering motor includes a steering motor gear 524 which meshes with a corresponding gear surface on the bottom surface 526 of the stationary gear 504, as shown in **Figure 5B**. As shown in **Figures 5A** and **5B**, when activated, the steering motor gear 524 rotates and traverses along the bottom surface 526 of the stationary gear 502, thereby steering the wheel assembly 412 about the axis 98. The steering motor 508 is preferably configured to rotate the steering motor gear 524 in either direction to rotate the rotatable base 504 clockwise or counterclockwise about the axis 98. It should be noted that the steering motor is not limited to the configuration shown and alternatively has any other appropriate configuration.

[0078] The wheel assembly 412 is therefore able to rotate the tires 500 to any desired angle with respect to axis 98. The wheel assembly 412 is thus to rotate to any desired angle to move the transporter 118 in any desired direction. This omni-directional configuration allows the transporter 118 to operate in non-rectangular structures, such as the garage 100 shown in **Figure 9**. In addition, the omni-directional configuration of the wheel assemblies 412 allow the transporter 118 to make sharp turns around other vehicles if needed. Further, the omni-directional ability of the transporters 118 allow the transporters 118 to rotate around its control axis (97) (**Figure 4A** in minimal space) as stated above, without the use of external equipment.

[0079] As shown in **Figure 5B**, a rotational position sensor 528 is mounted on the bottom of the rotatable base 502. The rotational position sensor 528 is not shown in **Figure 5A** for clarity. The rotational position sensor 528 utilizes a sensor gear 530 which meshes with the bottom surface 526 of the stationary gear 502 to measure the distance which the wheel 412 rotates. The sensor 528

communicates the measured data to the onboard computer 418 (**Figure 4B**) for use in the steering algorithms. Alternatively, the rotational position sensor 528 is integrated within the steering motor 508 or other device. Alternatively, the rotational position sensor 528 measures rotation at the pivot 518. Alternatively, the rotational sensor 528 uses optical, magnetic or electrical means to measure rotation of the wheel assembly 412 in relation to the transporter body 400. In another embodiment, the rotation position sensor is not included in the wheel assembly 412.

[0080] The tires 500 of the wheel assembly 412 are preferably driven utilizing the drive motor 514 and drive gear 516 shown in **Figure 5B**. In particular, the drive gear 516 is preferably mounted to the axle 512 such that rotation of the drive motor gear 514 causes the gear 516 to rotate about the axle 512. The tires 500 are rotated about the axle 512 by operating the drive motor and gear 514, thereby driving the drive gear 516, axle 512 and tires 500. The drive motor 514 is preferably configured to rotate in either direction to rotate the tires 500 clockwise or counterclockwise about the axle 512. The drive motor 514 for each wheel assembly is preferably individually controllable by the onboard computer 418. Alternatively, the motor 514 is located in line with the wheel axle 512 to provide direct power from the motor 514 to the axle 512. In such a configuration, one wheel is powered whereas the other wheel rotates freely. It is apparent to one skilled in the art that the wheel assembly 412 is not limited to the configuration shown and described herein. Therefore, any other appropriate configuration is alternatively contemplated to provide a completely rotatable wheel assembly capable of allowing the transporter 118 to move in any direction.

[0081] As shown in **Figure 5B**, the wheel assembly 412 is preferably a dual tire 500 configuration which is able to rotate when the transporter 118 is stationary. Alternatively, the wheel assembly 412 is a single tire configuration. The ability of the wheel assemblies 412 to rotate while the transporter 118 is standing allows the transporter 118 to make accurate turns without consuming space. In addition, the ability to angle and power all the wheel assemblies 412 independently enables the transporter 118 to rotate about the center 97 (**Figure 4A**) of the transporter 118. Each wheel assembly 412 is coupled to the onboard computer 418, whereby the onboard computer 418 control all

aspects of the operation of the wheel assembly. As stated above, it is preferred that each wheel assembly 412 is independently rotatable as well as independently operable by the onboard computer 418.

[0082] **Figure 6A** illustrates a top view of the preferred access bay assembly 600. **Figure 6B** illustrates a detail of the wheel guide positioning mechanism. The access bay assembly 600 shown in **Figures 6A** and **6B** is mounted within the access bay 112 and preferably includes two retractable walking surfaces 602 each preferably having a tire guide 608 for the vehicle's 99 wheels. In addition, the access bay assembly 600 preferably includes fixed transporter wheel guides 604 and one or more moveable wheel stops 606.

[0083] The transporter wheel guides 604 are disposed on the ground surface of the access bay 118. The transporter wheel guides 604 are positioned to ensure that the transporter 118 is properly aligned within the access bay 112 when entering and exiting the access bay 112. The walking surfaces 602 are preferably flat and include the tire guide 608 which protrudes vertically from the walking surface 602. Alternatively, the tire guides 608 are independent components not part of the walking surface. The walking surfaces 602 preferably include one or more roller mechanisms 610 (**Figure 5B**) underneath which allow the walking surfaces 602 to extend and retract in the Y and -Y directions, respectively. The wheel stop 606 is moveable in the X and Y directions and preferably moves into place before the vehicle drives onto the transporter 118. The wheel stop 606 stops the vehicle tire at a position that centers the vehicle 99 on the transporter 118. The walking surface 602 and wheel stop 606 are coupled to the central computer 104, whereby the walking surface 602 and wheel stop 606 traverse to the appropriate position based on the dimensions of the vehicle 99 which are measured at the entry station 12. As stated above, the central computer provides measurement information of the vehicle 99 to the access bay 112 when the vehicle 99 arrives at the garage 100. The access bays 112 utilize the measurement information to extend the walking surfaces 602 and wheel guide 608 the appropriate distance to properly load the vehicle 99 onto the transporter 118. The transporter utilizes

the measurement information to properly position itself along the X-X axis to allow the wheel stop to position the vehicle in the properly located position.

[0084] The process of loading the transporter 118 with the vehicle will now be discussed. The walking surface 602 preferably moves to the extended position before the vehicle 99 is driven onto the transporter 118, whereby the position of the tire guide 608 substantially matches the vehicle's 99 wheel track dimension. In addition, the wheel stop 606 is moved to the position which substantially centers the vehicle 99 onto the transporter 118. As shown in **Figure 6A**, the vehicle 99 is driven onto the transporter 118 in the direction indicated by the arrows, whereby the vehicle 99 drives up the ramp 612 onto the transporter 118. Once the vehicle 99 is properly positioned onto the transporter 118, the driver and passenger(s) exit the vehicle 99 onto the level walking surface 602 and exit the access bay 112. Once the access bay 112 is cleared of persons, a status which is preferably configured by sensors (not shown) in the bay 112, the walking surfaces 602 as well as the wheel stop 606 retract. The central computer 104 is notified that the loading execution has been completed, and the transporter 118 is authorized to execute the instructions provided to it by the central computer 104. It should be noted that the unloading execution is preferably the reverse procedure as the loading execution with the exception that the wheel stop remains retraced during the unloading execution.

[0085] It should be noted that the access bay 112 is alternatively recessed into a concrete slab or other level surrounding surface. Alternatively, the access bay 112 is raised above the surrounding surface, whereby the access bay 112 would include additional ramps for vehicle and passenger access to the transporter surface. In certain applications, the access bay may also be built into the elevator or lift 110, whereby the vehicle is directly driven into the elevator or lift 110. It is apparent that the access bay 112 described above is just one embodiment and is not limited to the embodiment described.

[0086] **Figures 7A** and **7B** illustrate an aboveground transporter storage device. **Figure 7C** illustrates an in-ground transporter storage device. Both types of storage devices 114 are configured to store transporters 118 when not in use. While the garage 100 operates effectively without a transporter

storage device 700, 700', the devices 700, 700' increase efficiency in the system 100 by reducing the number of empty transporters 118 on the levels that need to be moved to facilitate any given protocol. In both cases, the transporter is guided to the storage device 700, 700' by the central computer 104, and the storage device 700, 700' undertakes the necessary storage procedure.

[0087] The device 700, 700' preferably includes a recharging dock 706, 706' that couples to a rechargeable battery port (not shown) on the transporter 118 and recharges the battery 416 (**Figure 4C**) on the transporter 118. The recharging dock 706, 706' is preferably integrated into the transporter storage device 700, 700'. Alternatively, the recharging dock (not shown) is a freestanding standing device independent of the storage device. For instance, a battery capacity indicator (not shown) on the transporter 118 reports the status of the battery to the central computer 104, whereby the central computer 104 initiates a recharging protocol when required. In the embodiment that the recharging dock 706, 706' is integrated in the storage device 700, 700', the protocol involves directing the transporter 118 to the storage device 700, 700' for recharging.

[0088] The storage device 700 shown in **Figures 7A** and **7B** receives and dispenses the transporters 118 through the bottom portion by mechanical operation. To receive a new transporter 118, the storage device 700 inserts retractable fingers 702 at lifting points beneath the bottom transporter 118 (**Figure 7B**). The storage device 700 then lifts the transporter 118, as well as the stack of transporters 118 above it, a sufficient distance to enable an arriving transporter 118 to slide beneath the suspended stack (**Figure 7A**). When the arriving transporter 118 is in position, the mechanism lowers the stack onto the arrived transporter 118 to await the next arriving transporter. If a transporter is requested from the storage device 700, the retractable fingers 702 move into position beneath the second stacked transporter 118 from the bottom and lifts the transporter 118, as well as the stack above it, a sufficient distance to allow the bottom transporter 118 to move out of the device 700. Once removed, the device 700 lowers the stack to its resting position to await future arrivals or removals. Alternatively, the transporter 118 on top of the stack, instead of the bottom, is received and dispensed. The storage device 700 is coupled to the central computer 104, whereby the storage

device 700 executes protocol instructions provided by the central computer 104 to properly store, recharge and dispense transporters 118.

[0089] The top access storage device 700' shown in **Figure 7C** fits within a recessed construction 708' below the grade floor and dispenses at access level 102. The recessed storage device 700' includes of a lifting device 702' such as a hydraulic lift or scissors lift that lowers and lifts the stack of transporters 118 as required. In one embodiment, guides adjacent to the storage device 700' direct the precise positioning of the transporter 118 on top of the stack such that the transporter 118 simply propels off to its designated destination once at access level 102. The storage device 700' is coupled to the central computer 104, whereby the storage device 700' executes protocol instructions provided by the central computer 104 to properly store, recharge and dispense transporters 118. It is apparent to one skilled in the art that the storage device in the present invention is not limited to the embodiments shown and alternatively have any other appropriate design to selectively store and release transporters.

[0090] **Figure 9** illustrates a non-rectangular parcel of land in which the alternative embodiment at the garage 800 is located. In this example, the different orientations of the transporters reflect site-specific factors such as the presence of different column grids associated with different buildings above the garage level. This embodiment 800 illustrates the ability of the omni-directional transporters to effectively operate in a non-rectangular parking setting which is otherwise difficult and inefficient for either conventional parking or orthogonal-based prior art automated parking systems. Thus, the omni-directional wheel assembly of the transporters makes possible transporter movement in the alternative garage to create floating circulation paths, irrespective of the geometry of the parcel.

[0091] As stated above, prior art parking system require large amounts of on-site installation of specialized fixed equipment. The costs associated with the installed equipment and construction is not easily financed through conventional real property capital sources, because the specialized characteristics of the prior art systems fail to be appealing to underwriting criteria such as useful life and

proven long term value. The present system is in the form of individualized mobile transporters and devices which can easily be removed from a building and reused elsewhere. In addition, the present system is able to be used in existing parking garages, whereby a minimal amount of construction is needed to implement the present system. As a result, the cost of employing the present invention in a parcel of land can be financed through equipment leases and other flexible financing options which are more attractive to prospective purchasers of the system. In addition, the characteristics of the present system described above allow the system to be easily updated and modified. Therefore, the present system will not easily become obsolete, thereby preventing the value of the property, in which the present system is employed, from diminishing in value.

[0092] The foregoing description of preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations will be apparent to one of ordinary skill in the relevant arts. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, thereby enabling others skilled in the art to understand the invention for various embodiments and with various modifications that are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims and their equivalence.